

**ARMY TACMS CDPU FIELD TEST
FT.SILL OKLAHOMA
7 JUNE 1988**



**CODAR
TECHNOLOGY
INC.**

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UNCLASSIFIED

**Codar Technology, Inc.
Military Systems Division
1500 Kansas Ave., Bldg., 2E
Longmont, Colorado 80501 USA
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MILITARY SYSTEMS DIVISION
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PART 1

INTRODUCTION

This report covers a series of environmental and operational tests on the Army TACMS CDPU which were conducted from 7 June 1988 through 9 June 1988 at Ft. Sill Oklahoma. This test program was basically joint ventured: The Army supplied a M577 vehicle and crew with Codar and LTVMEG underwriting the rest of the cost for personal, test equipment and data analysis.

The purpose of this test was to demonstrate the ability of a pre-production CDPU to operate in the M577 tactical environment.

BACKGROUND

In August of 1987 Codar and LTVMEG conducted a preliminary CDPU related field test at Ft. Sill. The purpose of this exercise was to determine the tactical temperature, shock and vibration environment that the CDPU would operate in. Testing was conducted using an instrumented mock up chassis with dummy disk drives that mechanically simulated the planed CDPU configuration. (The CDPU is based on Codar's standard Model 600M ruggedized chassis.)

The reader is referred to the "M577 EQUIPMENT SHOCK, VIBRATION & TEMPERATURE FIELD MEASUREMENT PROGRAM" report dated 15 September 1987 for additional information on the 1987 test program. This year we concentrated on new data with a sufficient amount of overlap to confirm that our 1987 results were valid. As an example, this year temperatures were measured in the vicinity of the CDPU while last year temperature profiles were recorded throughout the entire vehicle.

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OBJECTIVES

The overall goal was to obtain field time on the CDPU prior to scheduled production. The specific technical objectives of this test were as follows:

- 1. Operation of a complete dual MicroVAX CDPU in the M577 using 28 volt vehicle power.*
- 2. Operation without the PCU which would simulate a worst case tactical power environment (PCU bypass mode).*
- 3. Operation of the CDPU disk system with the vehicle moving.*
- 4. Operation of the CDPU for an extended period at high temperature (heat soak) in an effort to induce system failure.*
- 5. Measurement of operational shock and vibration time series data using knowledge gained from the 1987 test program.*
- 6. Verification of the CDPU vehicle mounting system within the M577.*
- 7. Testing of the CDPU air filtration system in a high dust and dirt environment.*

All objectives were successfully completed during the allotted field time.

FIELD TEAM

Codar Technology personnel included Michael Evans, President, David Breakfield, Director of Mechanical Engineering, and Jim Schilling, Mechanical Engineer. Steve Perry of LTVMEG provided logistics and coordination with the Army personal.

The Army provided two individuals to operate the M577, SP4 Alexis Shelton and PFC Dieter Zimmerman. The technical competence of SP4 Shelton concerning the vehicle and related electronics was of particular benefit during testing. He seemed to quickly comprehend the general characteristics of the CDPU and its planned future missions. Earl Young of LTVMEG was in charge of arrangements with Ft. Sill in advance of the field program. Our technical point of contact at Ft. Sill was Mr. Richard VanHorn of TSM-FSC3. The M577 MLRS vehicle was provided by the 2d Bn, 18 FA.

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INSTALLATION

The CDPU was installed in the M577 (vehicle B-10) in its operational location (the printer had been moved). As the vehicle table had not been drilled, the CDPU was secured to the FDDM table using clamps. The CDPU itself was equipped with the tactical mounting brackets.

One problem was encountered during installation. The vehicle had a pair of KY-57s installed on the bottom side of the radio shelf (apparently a non standard location). This position interfered with the top of the CDPU and required that the KY-57s be moved.

The actual first time installation required about two hours including moving the KY-57s. Army personal inspected the installation and voiced approval. No special tools were required. Installation was conducted in the parking lot of the motor pool.

Vehicle +28 volt power was connected to the CDPU using a custom cable supplied by LTVMEG. Power was obtained from a MX7773 transient suppresser which is apparently a slightly different model than the MX7778 which we had expected to find in the vehicle.

INSTRUMENTATION

The CDPU was instrumented with two Dytran accelerometers with calibration factors of 50 mv (0.05 volts) per G of acceleration. The first accelerometer, a tri-axial device, was installed on the top of the CDPU using one of the lid screws. The second accelerometer, a vertical sensor, was mounted inside the CDPU on the shock mounted peripheral tray between the disk drive and the TK50 cartridge tape drive. The accelerometer control electronics were mounted on top of the table to the left of the CDPU and under the radios.

The accelerometers and control electronics were returned to Dytran following the test for calibration and certification. The units were determined to be within calibration by Dytran.

One lesson learned in 1987 was that it is very difficult to both write documentation information on Polaroid pictures and stay alive while the M577 vehicle is tearing cross country. Last year's priority was documenting the accelerometer data pictures as they came from the digital oscilloscope.

This year priorities had changed. Prior to this years Ft. Sill test a portable Kenwood commercial digital oscilloscope, model CS-8010, was purchased which provide all required accelerometer documentation including voltage gains, time base, and date

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INSTRUMENTATION

and time on the screen. The scope was mounted on top of the KG-31 using straps and foam rubber for shock protection.

The accelerometer/oscilloscope system allowed simultaneously recording and storing both accelerometer channels with all required documentation. A Polaroid scope camera was used to record data from the screen of the digital scope.

A portable liquid crystal display terminal was mounted on top of the CDPU using foam rubber isolation and straps. This device provided a keyboard and display for operating the diagnostics which would be used for testing the CDPU. The terminal was connected to the systems console port of the DPU via CDPU test connector J17 on the rear panel.

A 28 volt DC to 120 VAC 60 Hz power converter and 12 volt car battery were mounted under the FDDM table in the space that would normally be occupied by the PCU. The battery did not require recharging during the test program due to the low current drain of the instrumentation system.

Two type K thermocouples were installed in the M577. The first was mounted slightly above the CDPU below the radio shelf. This device was used to provide vehicle interior "ambient" temperature measurements. A second thermocouple was mounted inside the CDPU in the airflow behind the disk drive and in front of the card cage. Temperature measurements were made using a portable Fluke two channel unit which is under MIL-I-45208A calibration.

The over all instrumentation system and methodology was similar to what was used in the 1987 Summer test at Ft. Sill. No problems were noted with the instrumentation system with the exception of the terminal as discussed in the heat soak test section. Two CDPUs were onhand in case we had a failure with one during testing. The second unit was not needed.

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DOCUMENTATION

All accelerometer data was essentially self documenting. Each Polaroid photo was assigned a log number with descriptions of the terrain and conditions recorded against the same log number in a note book. Temperature data was manually entered in the note book. All data was transcribed into a project log book at the end of the day.

The installation was documented using a 35 mm SLR camera with both color negative and transparency film (Appendix A). A local professional photographer was hired who shot 2 1/4" film plus 3/4" video tape. The KG-31 was covered with duct tape during the photo sessions.

Video was also shot of the M577 vehicle while executing maneuvers over different terrain (to document how much dust the M577 kicked up while moving).

PART 2: TEST RESULTS

GENERAL

CDPU serial number 152 was used for all testing. This system contained a full complement of modules for both the CDU and DPU. All testing was conducted using the DPU side of the system as it contains the Winchester disk drive and the TK50 cartridge tape drive.

TEST DIAGNOSTICS

Testing was conducted using the Codar Parse diagnostics package. Individual test programs are included for the MicroVAX II CPU, memory, disk drive and controller, TK50 controller and tape drive, serial interface, and the DEQNA Ethernet interface. Diagnostics were loaded in to memory using the DPU TK50 cartridge tape drive.

The diagnostics were used in two modes. During the moving vehicle test the disk module was run in a continuous loop to determine performance of the drive under vibration. Heat soak test were conducted with the diagnostic normally in an automatic mode where it sequenced through all test.

The disk module was also run continuously during heat soak and in the auto sequencing mode while moving to insure that there were no holes in the methodology. The diagnostics were controlled from the portable terminal which emulated a DEC VT100 terminal.

The CDPU was tested extensively on return to Codar in Longmont, CO. All modules including the CDU interfaces (Simpact, TACFIRE, etc.) were fully functional. No internal damage or fraying of cables was detected.

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DISK DRIVE VIBRATION TEST RESULTS

The CDPU itself never made an error during the three days of testing. Soft errors were produced on the CDPU disk drive while the vehicle was moving, which is not part of the planned operational scenario. However, Codar's goal is to be able to operate the disk drive while moving with out read or write errors.

The Micropolis disk drive produced no errors or problems with power on and the disk spinning while the vehicle was moving. The errors occurred only when attempting to read or write to the drive while moving and then only at high speeds on pavement.

On 7 June 1988 between 1430 and 1600 hours a series of disk related tests was conducted with the vehicle moving over terrain in the vicinity of Moway House. The vehicle traversed varied terrain including gullies, washed out rocky areas and pavement at speeds between 10 and 25 mph. (The vehicle speed was determined by what the driver felt comfortable with.)

During this testing five or six recoverable disk related errors were noted (they were hard to document while moving as they scrolled off the CRT display screen). The vehicle was stopped and the disk drive reformatted which in itself is a comprehensive test of the complete CDPU and power system. No errors were noted during formatting, which takes about 30 minutes.

Following reformatting, the error rate (all five or six) seemed to drop by about 50% while moving. This particular drive had not been formatted since prior to ESS testing at Codar as the technical staff was curious about what if any effect accumulative shipment and installation handling might have on the drive. The conclusion is that the disk drives should be formatted, when possible, following installation in the vehicle.

The total error rate before and after was so low that it is difficult to draw absolute conclusions. The reformatting probably compensated for some thermal expansion in the hot vehicle and minor track "shifting" due to transportation. The proposed Reliability Enhancement Program should answer many of these disk related questions.

On 8 June 1988 the moving disk test was repeated while the vehicle was running at 20 to 22 MPH on a combination of gravel and paved roads. Engineers detected two separate write errors while on pavement. High speed on pavement seems to produce the most errors due to the high vibration levels of the vehicle track.

The drive was powered up and running at all times in the vehicle. This allowed checking of a previously identified potential problem with the vehicle mounting of

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DRIVE TESTING (Continued)

the CDPU. The basic problem is a high level resonance (Q of about 10) caused by the fact that the CDPU is mounted low on the sides rather than in a standard rack.

This problem showed up during the ATACMS required ESS random vibration testing. The net result is that the CDPU is subjected to higher vibration levels than it normally would experience. Codar has tested and incorporated a fix, with LTVMEG, which eliminates this problem.

However, the CDPU used for this testing did not have the new vibration resonance modification. The result at Ft. Sill was that the disk was subjected to elevated vibration levels. Codar's conclusion is that the CDPU disk system should be capable of operating error free while the vehicle is moving. (Cobble stone in Germany may be the exception.) This hypothesis will be confirmed during the next scheduled Ft. Sill test using a modified (now standard) CDPU.

TEMPERATURE TESTING

Much of the time was spent with the vehicle closed up and the CDPU operating in a heat soak mode. Testers verified with the Army that this is not SOP and was in fact a worst case scenario. In a tactical environment, the rear ramp would normally be dropped with camouflage netting deployed over the vehicle. The goal, however, was to try and simulate a worst case environment.

Fortunately the right days for heat testing were selected. On 7 June the temperature inside the M577 was 95° F when installation and power up of the CDPU were completed. Things got worse from there. On 8 June the temperature set a record high of 105° F at the Lawton airport. The thermometer inside the rental car with the windows down in the "shade" registered 107° F.

The most severe temperature testing was an intentional heat soak on the afternoon of 8 June. This testing was conducted by a stream which runs through Ft. Sill. We had the M577 vehicle in partial sun with the cars in the shade. The M577 was running with the rear ramp up and the top hatch closed.

The BCU was not powered up most of the time as the unit was concerned about possible (probable) heat damage. They did turn the BCU on for about 30 minutes at 1520 so testers could measure the lid temperature as an indication of internal temperature.

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TEMPERATURE MEASUREMENTS AT 1505 ON 8 JUNE 1988

MEASUREMENT LOCATION	TEMPERATURE
1. Outside Ambient Air In Shade	101° F
2. CDPU Inlet Air (Front of CDPU)	108° F
3. 3/4 " Above CDPU	111° F
4. Inside Disk Drive Canister	121° F
5. Inside TK50 Tape Canister	119° F
6. + 5 Volt Power Supply Heat Sink	129° F
7. + 12 Volt Power Supply Heat Sink	121° F
8. CDPU Lid Surface Temperature	112° F
9. BCU Lid Temperature (after 30 minutes)	127° F
10. Internal CDPU Sensor On PCM Module	118° F
11. Internal Thermocouple In Air Flow	110° F

These measurements almost represent worst case conditions. At one point on 8 June the temperature was measured at 124° F above the CDPU although this value was not documented in the log book. When the vehicle was moving, temperatures would drop somewhat due to airflow through the vehicle. In any event, it was very hot for all concerned.

Testing was conducted continuously for three hours during the heat soak on 8 June. (This was in addition to several other vehicle closed heat soaks of shorter duration on 6 June and 7 June which resulted in slightly lower internal vehicle temperatures - about 100° F.)

The basic test mode was to run the Parse diagnostic continuously on all devices in the DPU. No errors were recorded during these test in spite of the high temperatures. This confirmed operational lab testing previously performed on the CDPU at an ambient temperature of 140° F (60° C) without error. The program requirement is 50° C or 122° F.

TEMPERATURE MEASUREMENTS (continued)

One significant conclusion concerns the CDPU memory. DRAM (Dynamic Random Access Memory) uses electric charge stored on semi-conductor capacitors. The higher the temperature the faster this voltage decays and the more often the memory cell must be "refreshed" (an automatic re-write procedure inside the chip). We did not detect a single memory error during the entire field test (or previously in the lab at 60° C). This result increases confidence in DEC's memory design.

This year we left the engine running as this vehicle did not have an external generator (removed for maintenance). When running, the engine pulls a considerable amount of intake air through the crew compartment. The result is that the interior air is close to the outside air temperature (hot spots were found over the radios and the BCU due to restricted air flow along the sides). This may also explain why the crews complain that the vehicle is so cold in the winter.

The fans in the CDPU significantly improved the airflow around the radios and behind the BCU. Basically, the fans were taking "cool" (relative) air from the vehicle isle and discharging it against the side wall. This new forced air cooling could increase the MTBF of the radios and the BCU by 15% or more (estimated).

The temperature on top of the CDPU (112° F) was compared to the temperature on top of the BCU lid (127° F). These measurements are somewhat skewed as the CDPU had been on for three hours and the BCU for less than thirty minutes. (Again, the Army was concerned that leaving the BCU on would result in a high temperature failure.)

In any event, the temperature difference was significant. The obvious conclusion is that the inside of the sealed BCU is very hot with a significant rise above ambient. This leads to a considerably reduced MTBF as the failure rate doubles for every 10° C increase in component temperature. (Perhaps the Army would grant permission to open the BCU and instrument it for temperature during the next field test.) In contrast, the CDPU internal temperatures remained relatively close to ambient.

On 8 June problems were encountered with the portable terminal turning off due to the high temperatures inside the M577. This problem was solved by running the cable out the back door of the M577 with the terminal placed in the (cool) 101° F shade. The general conclusion based on limited testing is that the CDPU electronics will function in an elevated temperature environment.

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ELECTRICAL 28 V POWER TESTING

The voltage in the M577 was measured at 28.4 volts with the vehicle generator running and about two volts less with the vehicle turned off. (The supplied M577 did not have an external auxiliary generator.)

No problems were experienced using the M577's internal electrical system. The CDPU would transition without error from battery power to the vehicle's internal generator during vehicle starting. (Testers were concerned that transients or surges might cause the CDPU to shut down due to low or high voltage while cranking the M577 engine.)

The CDPU was operated in the bypass mode without the benefit of a PCU. This was accomplished with a cable which connected directly from the M577 transient suppresser to the CDPU. The CDPU was grounded to the power system using a wire at the transient suppresser end of the system.

SHOCK AND VIBRATION

A considerable amount of new shock and vibration time series data was collected which corresponds well with the 1987 data set. A tabulated summary data set is listed below:

TEST TERRAIN	VEHICLE	DISK
Hard Surface (asphalt)		
Traveling @ 25 mph (down hill)	9.6 G	2.8 G
Traveling @ 22 mph	12 G	3.2 G
Traveling @ 20 mph	14 G	3.2 G
Traveling @ 20 mph	12 G	3.2 G
Gravel Road		
Traveling @ 20 mph	12 G	3.2 G
Cross Country/Dirt road		
Traveling @ 15 mph	8.0 G	2.4 G
Traveling @ 15 mph	8.8 G	1.6 G
Traveling @ 12 mph	6.4 G	2.4 G
Traveling @ 10 mph	8.0 G	2.4 G
Cross Country/Dirt Road (Washboard)		
Traveling @ 15 mph	15.2 G	3.2 G
Baseline (engine ideling)	0.5G	.06 G

SHOCK AND VIBRATION

The testing terrain fell into three types of classifications; hard surface, gravel roads and cross country. The term hard road surface refers to asphalt roads that were encountered while relocating from the motor pool to the various field test sites.

Gravel roads are secondary roads found in several locations on the Fort. An abundance of dirt and cross country roads were found through out the Ft. Sill location. Although the terrain varied considerably, the correlation between terrain and vibration level became somewhat predictable.

Of the three classifications of terrain encountered, the hard surface was found to produce the highest levels of vibration with a resulting increase in "soft" disk errors. This high vibration level is a result of the impact of the vehicle tread onto the the hard road surface. This collision also results in severe structureborn noise that is somewhat deafening inside the M577.

The gravel road presented a similar but less severe vibration level than that of the hard surface. The cross country/dirt roads offered a reduction in structureborn vibration as well as noise level. Although the vibration levels were not absolutely repeatable, they were quite close and allowed for this general type of classification, as can be seen in the above chart.

The G levels are all peak-to-peak values as interpolated from the scope photos. The average vehicle vertical acceleration level was 9.68 Gs. The average disk drive vertical acceleration was 2.51 Gs. The resulting ratio of the two shows that 26% of the energy was transmitted or that we were providing 74% isolation.

The CDPU isolation system is obviously doing an excellent job of removing the high frequency vibration components which could cause long term fatigue in the disk and tape drives. This is best seen by looking at some of the actual scope photos in appendix B.

The highest frequency component that was visible in the accelerometer data occurs at a period of about 23 microseconds or 43 Khz. This seems to be directly attributed to the track noise.

The lowest frequency high level vibration signal measured was consistently around 14 ms or 71 Hz. This seems to correspond to a natural resonance of some sort in the vehicle which is well correlated with any sudden change in vehicle speed (turns, stopping or accelerating).

Shock pulses are not evident in the data set as they are difficult to capture and freeze while they are occurring. In general our time base was set on a fast sweep speed (vibration mode) which missed the low frequency shock pulse events. Based on our observations, terrain induced long period shock probably did not exceed 2 Gs. On

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the other hand one could consider the constant high vibration levels as simply repetitive shock pulses as defined in MIL-STD-810D.

All data was collected using scope photos in the time domain. A portable spectrum analyzer will be used for the next field test. Data on energy levels as a function of frequency requires a real time FFT or spectrum analyzer. This data will allow further optimization of the CDPU isolation design.

The conclusion is that the present CDPU disk drive isolation system is quite well matched to the M577 vehicle application. Again, it is noted that, as stated in the 1987 report, that the FDDM table isolation system is of no apparent value (much too stiff) but at least does not seem to be causing any harm.

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AIR FILTER TEST

The test CDPU had a white synthetic cleanable air filter installed in the front door. This material was selected as a trade off between reduced air flow and maximum dust arrestance. (The better the air filter the less the air flow and the higher the internal temperatures.)

Following return of the CDPU to Codar in Longmont, the air filter was removed and examined. A slight discoloration was evident where the filter material was not obscured by the front door grill pattern. This was quite encouraging based on the incredible rooster tail of dust kicked up by the M577 while moving on dirt roads. Based on time in the field it is estimated that the air filter could go about three weeks of full time use in the Oklahoma environment before it would require removal and cleaning.

No dust or contamination was found inside the CDPU which indicates that the filter is doing its job. Additional testing will be performed as part of the MOD 34 task.

GENERAL TESTING

The CDPU was opened at Ft. Sill prior to installation in the M577. No evidence of shipping damage or loose modules was found. The system was not opened again until it was returned to Codar in Longmont.

On arrival at Codar a detailed inspection was performed in an effort to detect chaffing on wire cables or other vibration induced problems. No problems were found.

Our primary conclusions from Ft. Sill were that production systems should have handles and captive hardware on the lid, both of which are planned. It also became quite obvious that the Army needs a shock isolated environmentally sealed storage container for the removable disk drives.

CORROSION

Whenever possible testers left the M577 totally closed up and parked in the sun (lunch breaks etc.). The goal was to try and induce failures through a combination of high temperature and humidity (the scenario described at PDR and CDR). Subsequent inspections of the CDPU at Codar showed no apparent damage.

It is acknowledged that three days is a relatively short test period. On the other hand, items have been known to rust in 24 hours under similar conditions. Conformal coating should eliminate any long term problems.

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MECHANICAL MOUNTING SYSTEM

Testers experienced no problems with the LTVMEG designed CDPU mechanical mounting system. The CDPU was easy to install and remove.

The only comment is that it is going to be extremely difficult to connect to the wire terminal post on the rear of the CDPU. Codar has developed under LTVMEG guidance a special decal for the left side of the CDPU which shows the location of the terminals and the positions of the wire/radio switch on the rear panel of the CDPU.

LTVMEG is working on a slide mounted system which would allow the crew easy (easier) access to the rear of the CDPU without actually removing it from the FDDM table. This would be a welcomed enhancement.

Another solution would be to locate the wire/radio switch and binding post on the left side of the CDPU which is exposed in the installation. This would be somewhat unconventional but very practical in the field.

CARTRIDGE TAPE DRIVE

Based on past experience, testers anticipated problems with the TK50 cartridge tape drive at high operating temperatures. On the contrary, the TK50 worked flawlessly.

CDPU diagnostics were stored on a TK50 cartridge. As a result, every time testers cycled the CDPU power they would reload diagnostics from the TK50. The TK50 thus received an extensive if somewhat informal workout during the three day test.

During the 8 June heat soak testers intentionally loaded the diagnostics from TK50 five times with no failures, crashes or apparent retries. Each load of the diagnostics required approximately five minutes of continuous accessing of the tape cartridge.

As a general comment, DEC seems to have improved the quality of the TK50 considerably over the last 18 months. Should it have problems, Codar strongly recommends the new TK70 for the production TDP. It is considerably faster, stores more data and is much more fool proof to operate. Codar is also concerned that DEC could discontinue the TK50 as it is becoming old technology.

The main complaint with the TK50 is that it is difficult to load properly. Poorly labeled switches must be operated in a precise sequence or the TK50 will go off in to never never land. This is not speculation. Testers spent 20 minutes trying to remember the correct sequence while at Ft. Sill. In contrast, the TK70 has superior human engineering characteristics.

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TEST SUMMARY

The following is a condensed version of how time was spent during the test program.

7 JUNE 1988

- | | |
|-------------|--|
| 0800 - 1230 | Installation, CDPU diagnostics & temperature measurements.
(96° F vehicle interior temperature) |
| 1345 - 1700 | Rough terrain shock and vibration testing at Moway.
(99° F vehicle interior temperature) |

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- | | |
|-------------|--|
| 0830 - 1105 | Dirt & paved road shock and vibration testing.
(87° F vehicle interior temperature) |
| 1105 - 1310 | Heat soak test with M577 vehicle closed in the sun.
Vehicle interior temperature at 102° F. |
| 1310 - 1600 | Operational heat soak testing at up to 124° F. |
| 1600 - 1645 | Paved road disk drive vibration. |

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- | | |
|-------------|--|
| 0830 - 0900 | Paved & gravel road vibration testing. |
| 0900 - 0945 | General CDPU testing with Parse diagnostics. |
| 0945 - 1200 | Documentation and installation photography. |
| 1200 - 1230 | Final equipment removal from the M577. |

FUTURE PLANS

Codar/LTV have requested vehicle time in September 1988 to conduct the third in a planned series of Ft. Sill tests. The basic goal in the next test will be to accumulate operational CDPU time with the vehicle moving.

The recent test demonstrated that the CDPU could in fact function in a stressful environment without failure. However, the test time has been rather limited (about the same impact as the future Red Stone Arsenal testing).

The next objective is to subject the CDPU to continuous shock and vibration over a period of several days as would be experienced in a combat situation. This should identify any latent problems that might develop due to fatigue, heat or humidity.

Our final objective would be to obtain shock and vibration data in the frequency domain in an effort to fine tune the disk drive isolation system.

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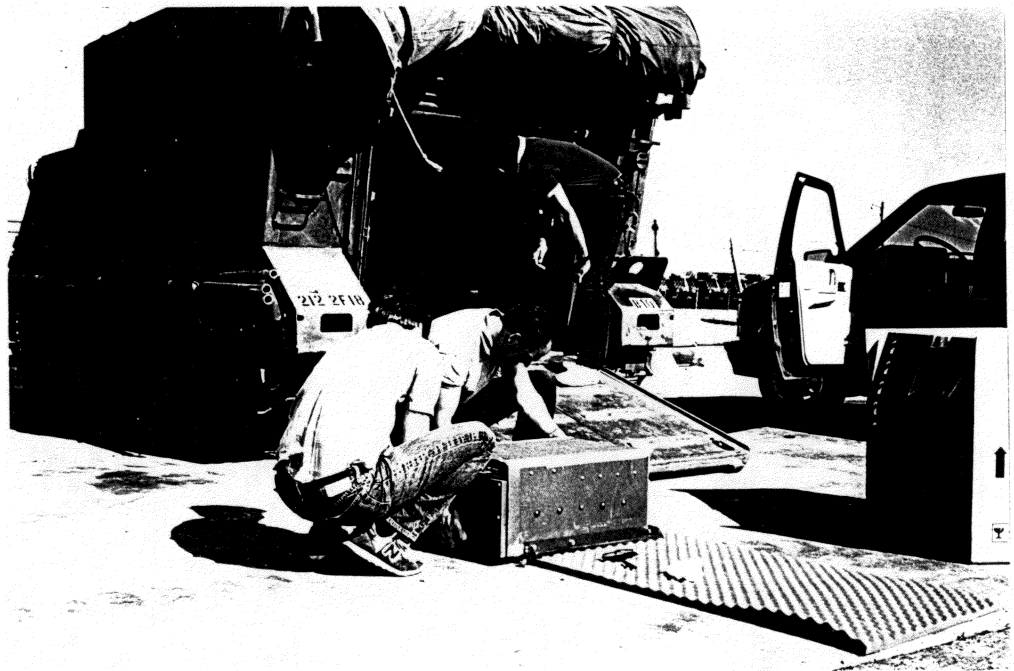
APPENDIX A

PHOTOGRAPHIC DOCUMENTATION

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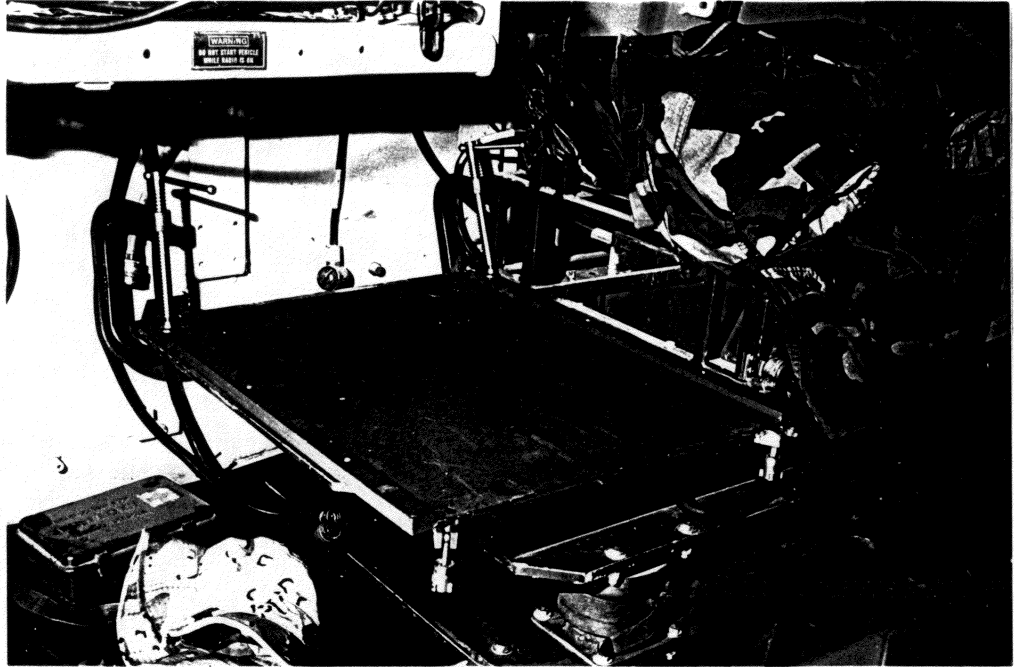


Lost at Ft. Sill.

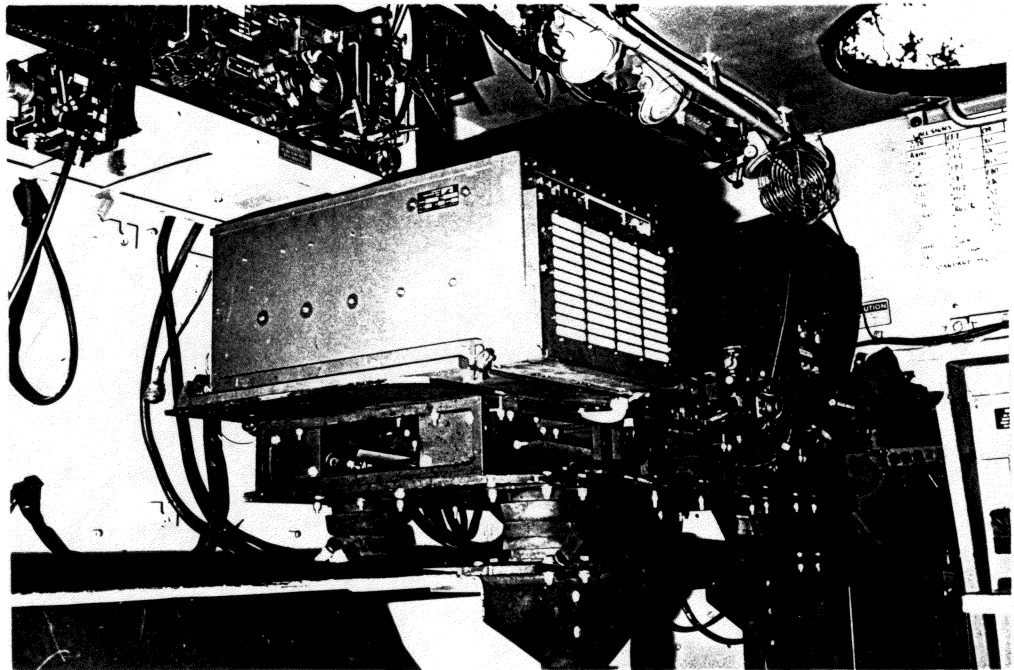


Installing CDPU in M577 MLRS test vehicle at Ft. Sill. Oklahoma motor pool parking lot.

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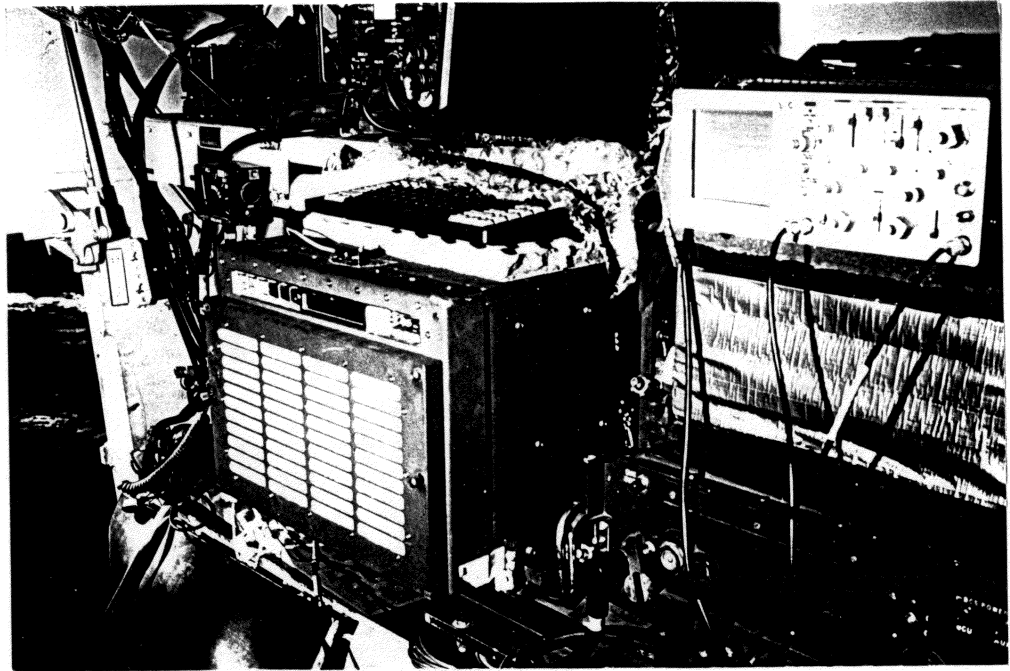


LTVMEG CDPU mounting tray on FDDM table. KY-57 Cryptos have been removed from below radio shelf.

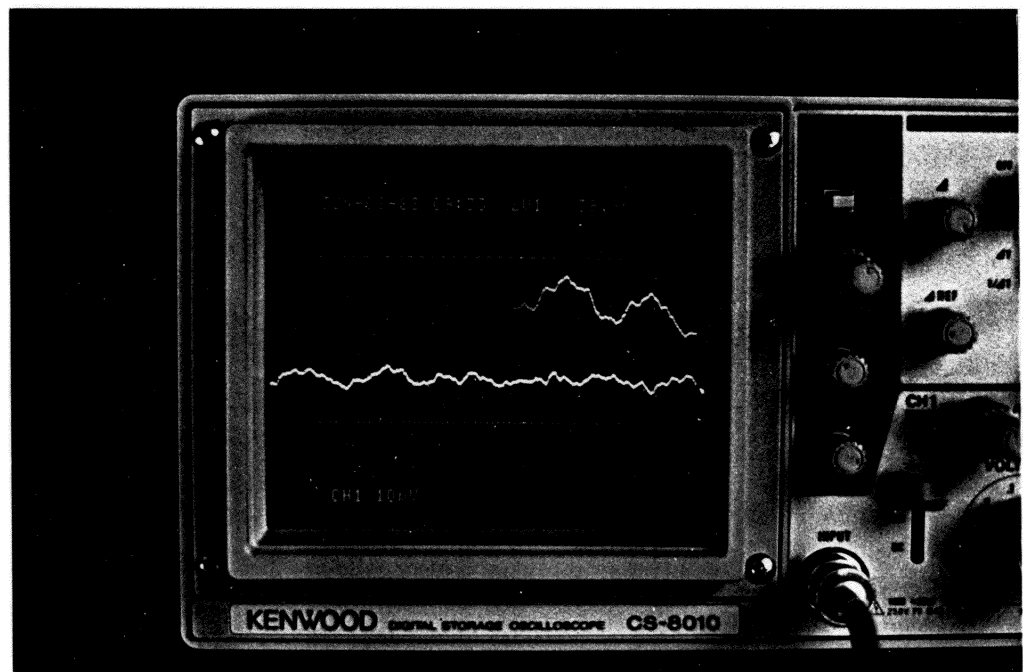


CDPU installed on FDDM mounting tray.

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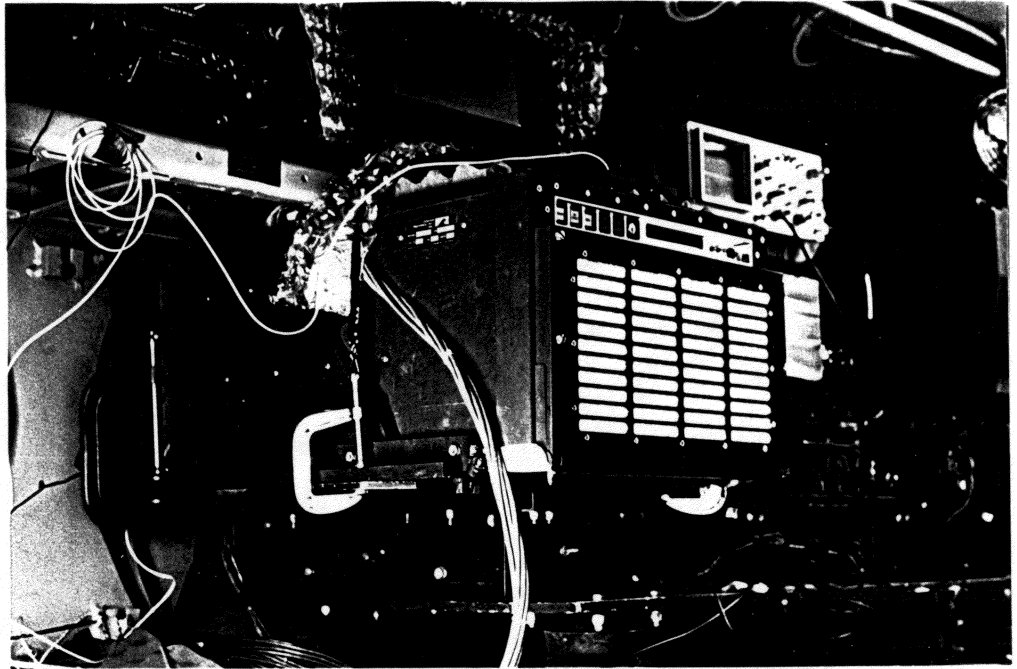


Tri-axial accelerometer on front top of CDPU with digital storage scope & VT100 emulating console terminal visible.

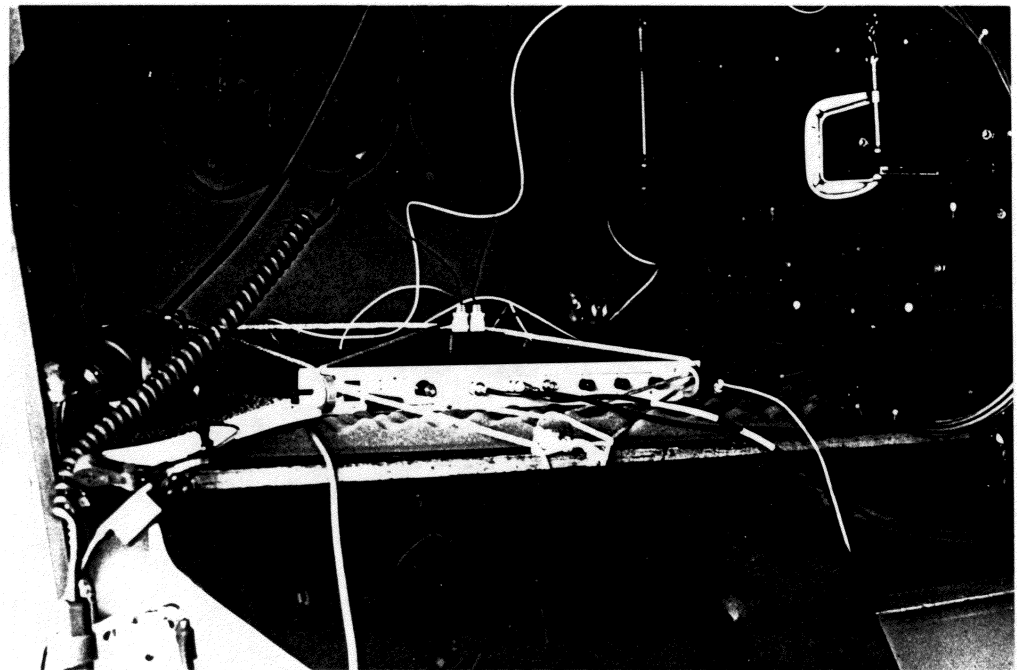


Top trace shows vehicle vibration level in vertical axis; bottom trace shows reduction of vibration on disk assembly.

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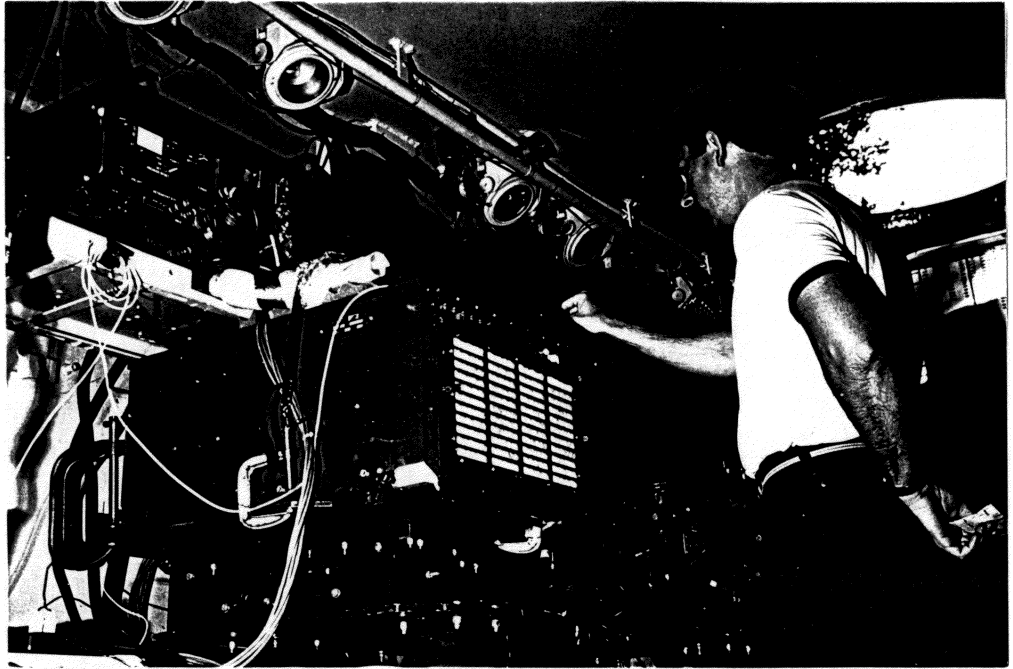


CDPU with test equipment installation. Console terminal which was used to run diagnostics is above CDPU.



Accelerometer control electronics & Fluke temperature measuring system.

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Running CDPU diagnostics during field testing.



M577 vehicle at start of heat soak test in 101 ° F ambient.

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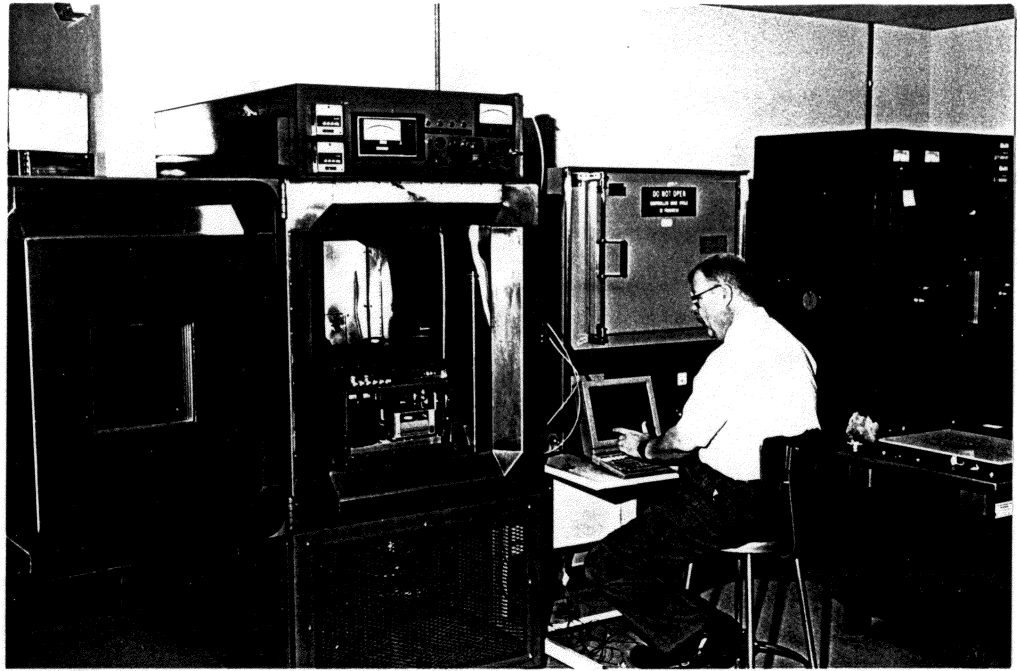


Running diagnostics during heat soak test on 8 June. Console terminal has been moved outside due to high heat.



M577 during a break in cross country vibration testing.

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Environmental testing of prototype at Codar. Temperatures ranged from -40°C to $+71^{\circ}\text{C}$. Vibration table in lower right.



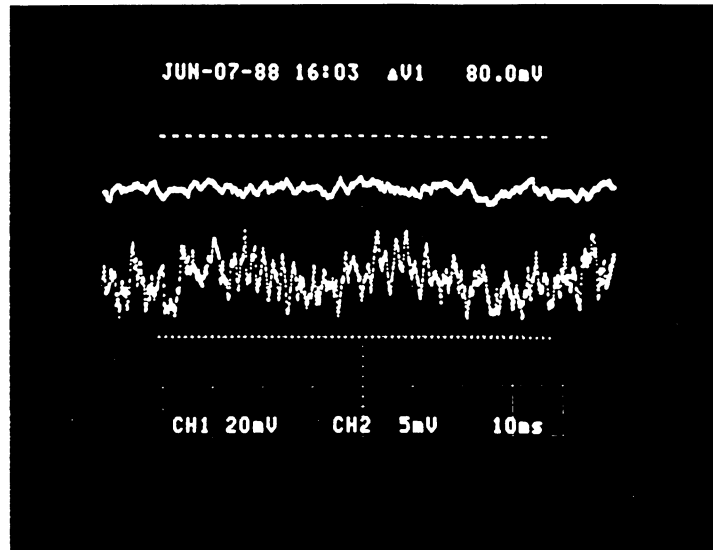
One of two Codar buildings in Longmont, Colorado where the CDPUs are manufactured.

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APPENDIX B

VIBRATION TEST DATA

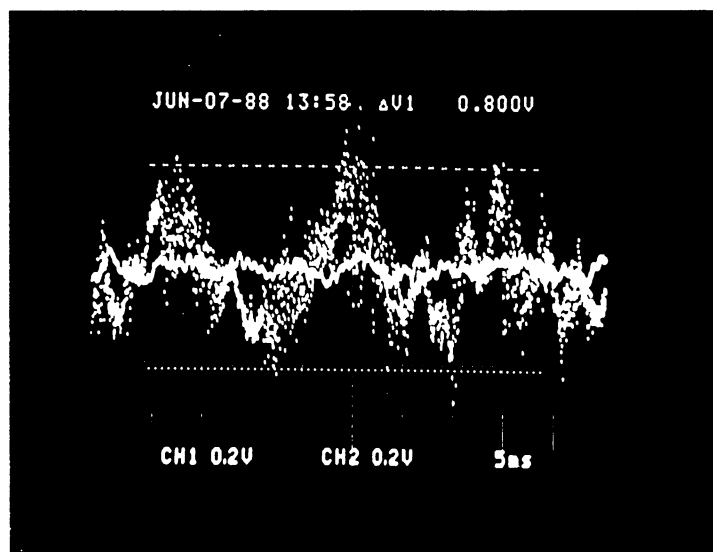
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Baseline level (engine ideling). Vertical axis.

Vehicle vibration level: 00.05 G

Disk drive tray: 00.06 G

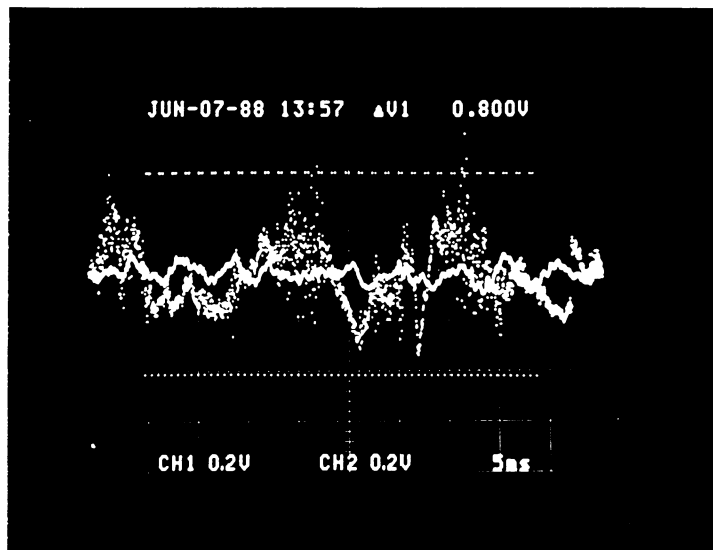


20 MPH on hard surface (asphalt). Vertical axis.

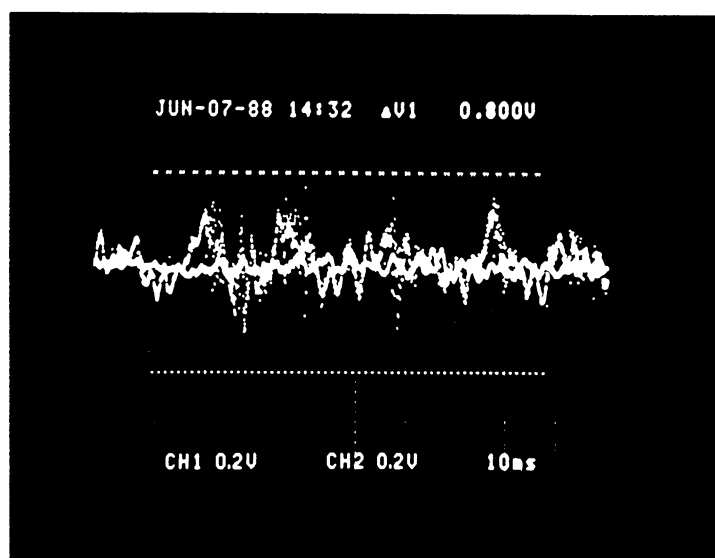
Vehicle level. 14.00 G

Disk drive tray. 03.20 G

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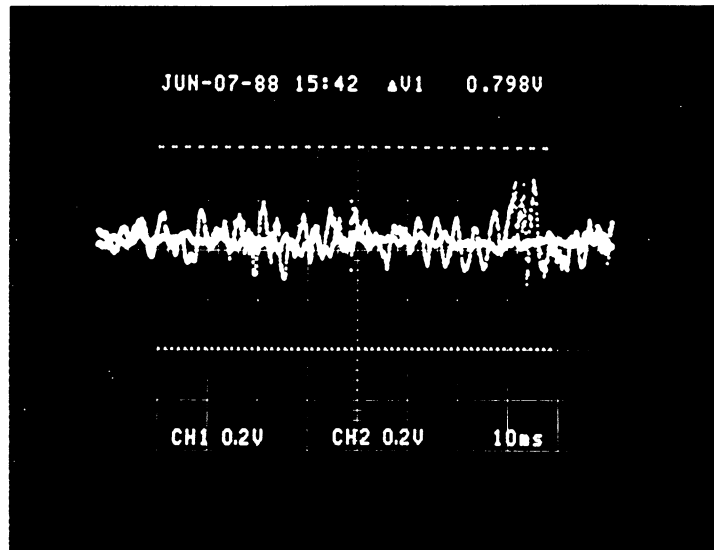


20 MPH on hard surface (asphalt). Vertical axis.
Vehicle level. 12.00 G
Disk drive tray. 03.20 G

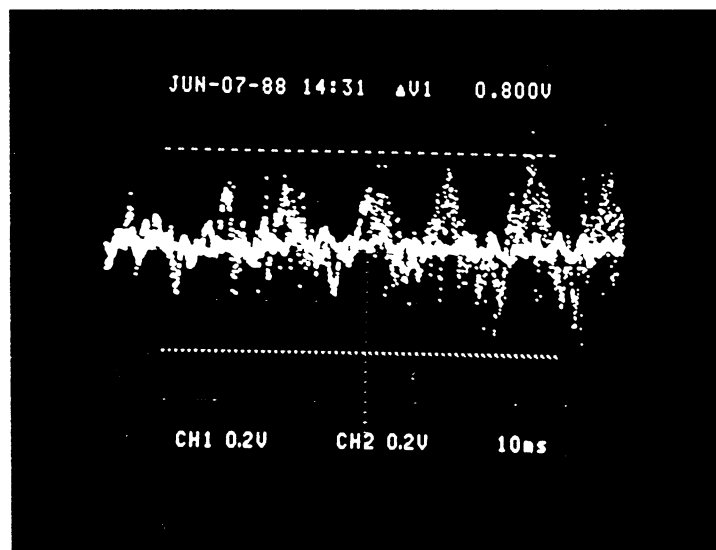


15 MPH cross country on dirt road. Vertical axis.
Vehicle level. 08.00 G
Disk drive tray. 02.40 G

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10 MPH cross country on dirt road. Vertical axis.
Vehicle level. 08.00 G
Disk drive tray. 02.40 G



20 MPH on gravel road. Vertical axis.
Vehicle level. 12.00 G
Disk drive tray. 03.20 G

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